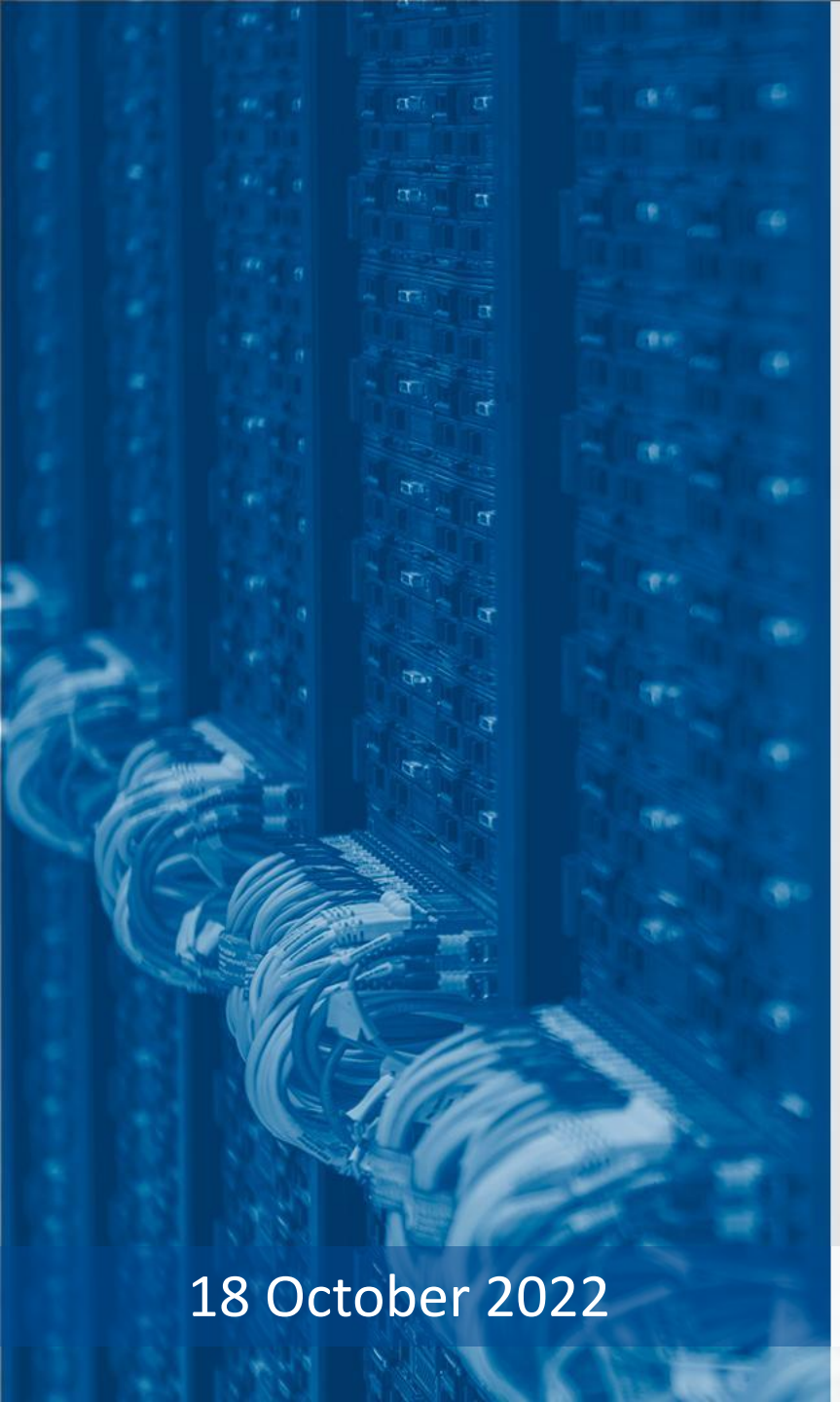

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Centro Nacional de Supercomputación

# MONARCH and Barcelona Dust Regional Center updates

J. Escribano and the Atmospheric Composition Group

18 October 2022

ICAP Monterey 2022

# The Atmospheric Composition group at BSC


Carlos P.


Oriol J.


María G.


Enza D.T.


Luka I.

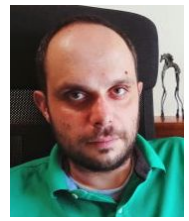

Marc G.


Sara B.


Jerónimo E.


Dene B.


Elina K.


*Visitors ex-BSC and collaborators*


Montse C.


Calum M.


Santiago E.


Roger G.


Franco L.


Hector N.


Ruben S.


Elisa B.


Adolfo G.


Cristina G.


Kevin O.

\+ *long list of close collaborators from CES, ESS and CVC Earth Sciences Department*

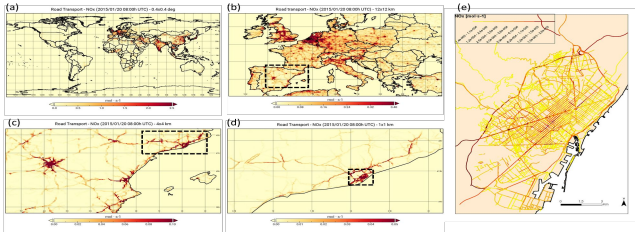
\+ ***Open positions (DA, Model dev., SDS)***

# Atmospheric Composition Group

**Understand, constrain and predict the spatiotemporal variations of atmospheric pollutants across scales along with their effects upon air quality, health, weather and climate**

## HERMESv3

A **python-based, open source, parallel and multiscale** emission model



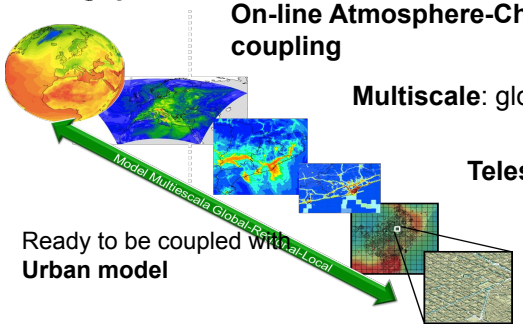
*Guevara et al. (2019, GMD)*
*Guevara et al. (2020, GMD)*
*Guevara et al. (2021, ESSD)*

## MONARCH

**On-line Atmosphere-Chemistry coupling**

**Multiscale**: global to local (1km

**Telescoping nesting**

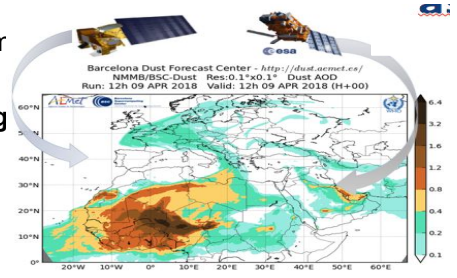



Ready to be coupled with **Urban model**

*Peng et al. (2019, QJMRS)*
*Kok et al. (2021a, 2021b, ACP)*
*Li et al. (2021, ACP)*
*Obiso et al. (in prep. Nat. Geo.)*

## LETKF DA

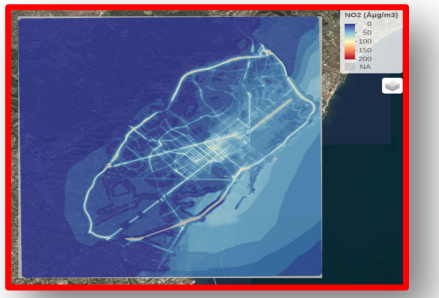
**Ensemble based Data Assimilation system**




*Escribano et al. (2022, ACP)*
*Escribano et al. (in prep, JAMES)*
*Di Tomaso et al. (2022, ESSD)*

## CALIOPE-Urban

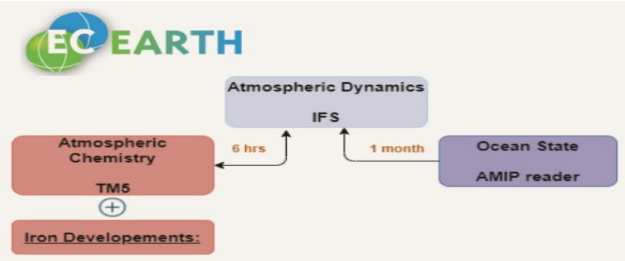
**Street-scale** dispersion model



*Benavides et al. (2019, GMD)*
*Benavides et al. (2021, ERL)*
*Rodriguez-Rey et al. (2021, TR-RES)*
*Rodriguez-Rey et al. (2021, STOTEN)*

## EC-Earth3-Iron

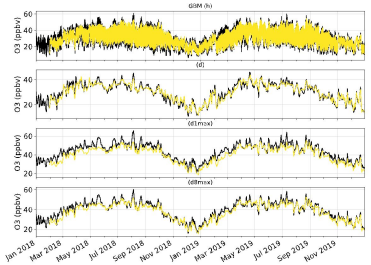
**Atmospheric iron cycle in EC-Earth**




Myriokefalitakis et al. (2021, sub, GMD)
Bergas-Masso et al. (in prep)

## Model Output Statistics

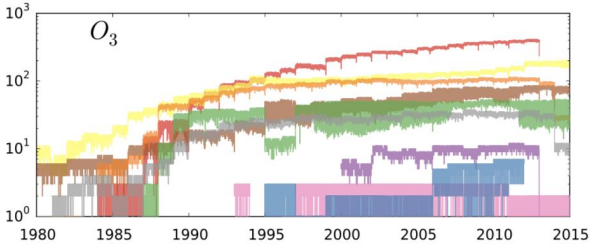
**Including machine learning**



Petetin et al. (2020, ACP)
Petetin et al. (2021, sub, ACP)

## GHOST

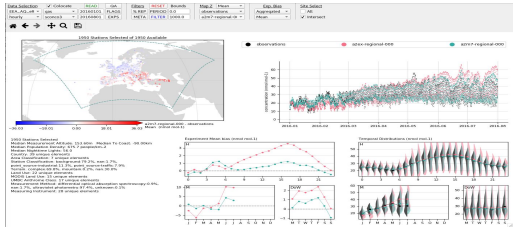
**Harmonised** treatment of observations




Bowdalo et al. (in prep, ESSD)
Bowdalo et al. (in prep, Nature Sust.)

## Providentia

**Dynamic/flexible evaluation** system



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Model and tool developments and related research outcomes

# MONARCH overview


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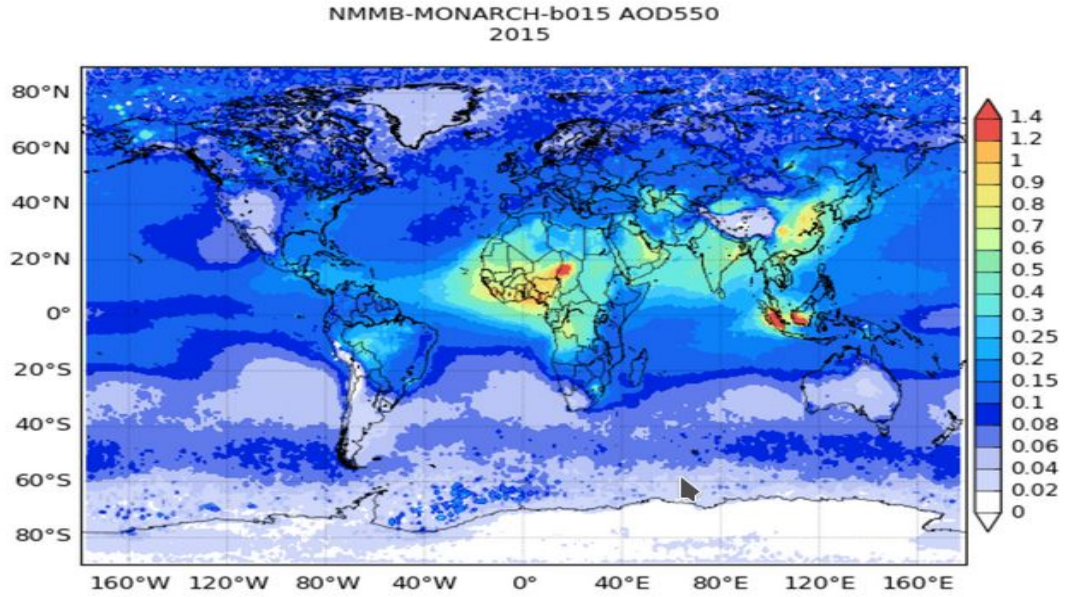
# MONARCH overview

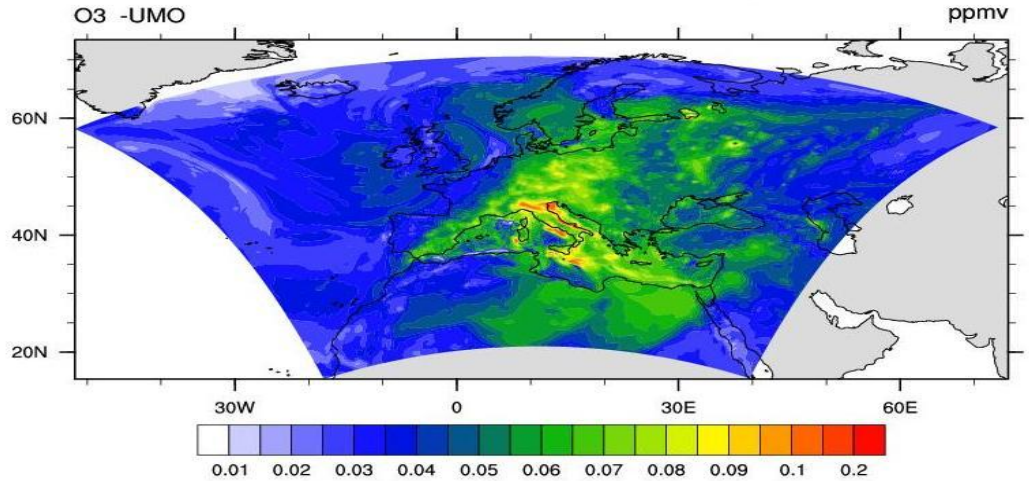
## Global




✔ *MONARCH contributes to the **ICAP global forecast aerosol** multi-model ensemble*
*http://icap.atmos.und.edu*

## Regional

***20100715 at 12UTC***




✔ ***BDRC** and **SDS-WAS** dust forecast*
✔ *Copernicus model **CAMS2_40a***
✔ *It will be implemented in*
***CALIOPE*** *(www.bsc.es/caliope)*
*AQ Forecast System for **Spain***

**And more products in: http://www.bsc.es/ess/**

# BSC Current forecasts and plans

CURRENT FORECASTING – DEVELOPED/AVAILABLE – UNDER DEVELOPMENT - PLANNED

| DOMAIN | GLOBAL (ICAP) | REGIONAL North Africa, Middle East and Europe (SDS-WAS) | REGIONAL Europe (Copernicus) |
|---|---|---|---|
| Model | MONARCH | MONARCH | MONARCH |
| Status | QO | O | O |
| Meteorology | Inline: NMMB | Inline: NMMB | Inline: NMMB |
| Resolution | 0.7x0.5 deg | 0.1x0.1 deg | 0.15x0.15 |
| levels | 48 | 40 | 24 |
| DA | LETKF | LETKF | LETKF (for analysis and reanalysis, not used as IC) |
| Assimilated Obs | VIIRS DT+DB (DU)<br>VIIRS DT+DB (ALL) | VIIRS DT+DB (DU) | EEA AQreporting Europe in-situ<br>TROPOMI (NO2), VIIRS (AOD) |
| Aerosol Species | DU, SS, BC,<br>POA, SOA bio,<br>SOA anthro, SOA fires, SU, NI | DU | *DU, SS, BC,*<br>*POA, SOA bio*,<br>SOA anthro, SOA fires, *SU*, NI |
| Gas phase chemistry | CBM-IV<br>CB05<br>ONLINE and CLIMATOLOGY | | CB05 |
| Emissions | HERMESv3 (HTAP v2, CAMS-GLOB)<br>MEGAN ONLINE | | HERMESv3 (CAMS-REGv5)<br>MEGAN ONLINE |
| Bio. Burn. Emissions | GFAS NRT | | GFAS hourly NRT |

# Other operational products:

# WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)

# Barcelona Dust Regional Center

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# WMO Barcelona Dust Regional Center is coordinating the WMO SDS-WAS activities for Northern Africa, the Middle East and Europe

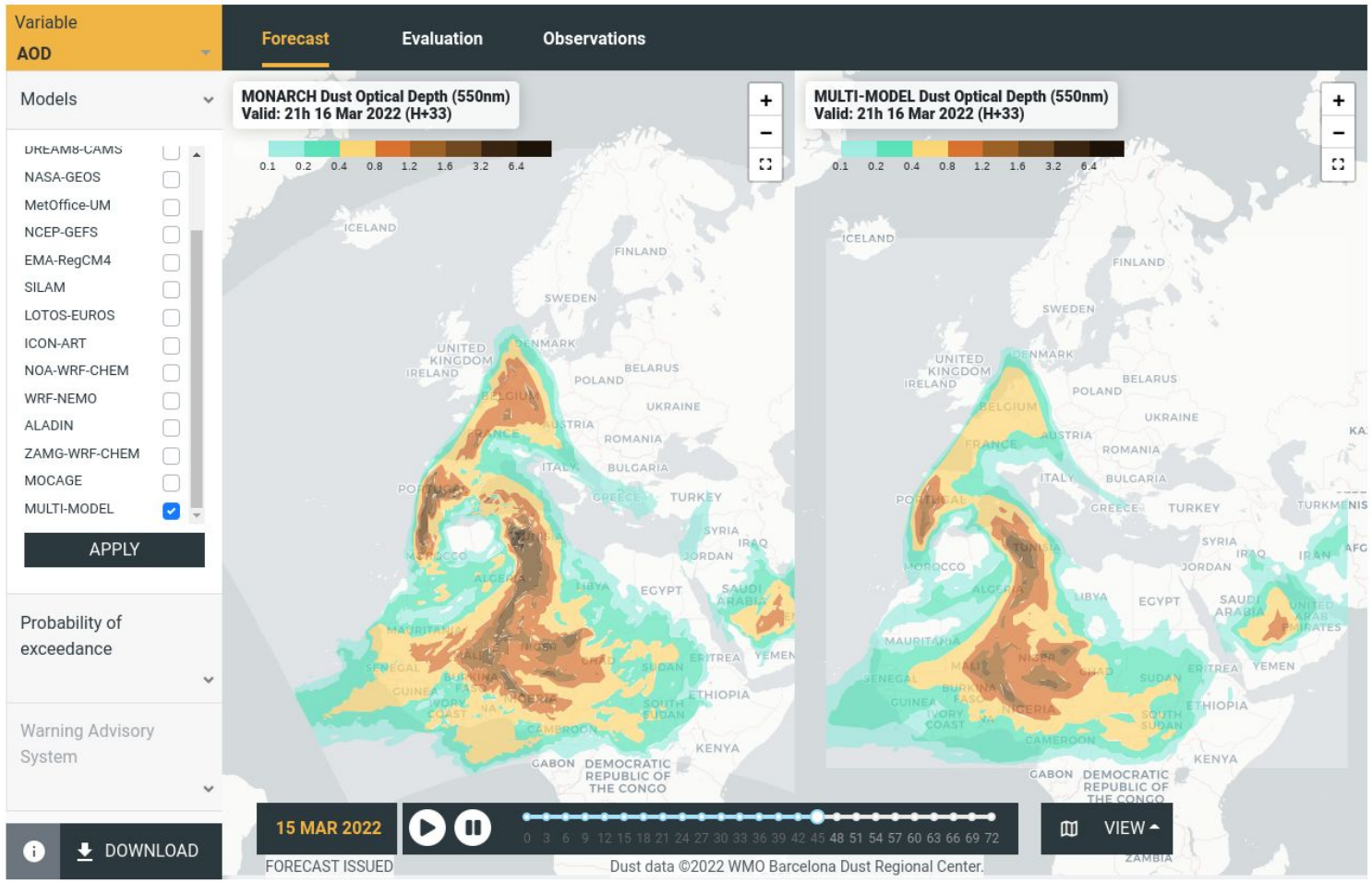
The WMO Barcelona Dust Regional Center is managed by AEMET and **BSC**

**https://dust.aemet.es/**
**@Dust_Barcelona**

More than 10,000 visits per month in our website

and more than 900 new Twitter followers in the last year (at present 3,948 followers in total)

# Daily Dust Products



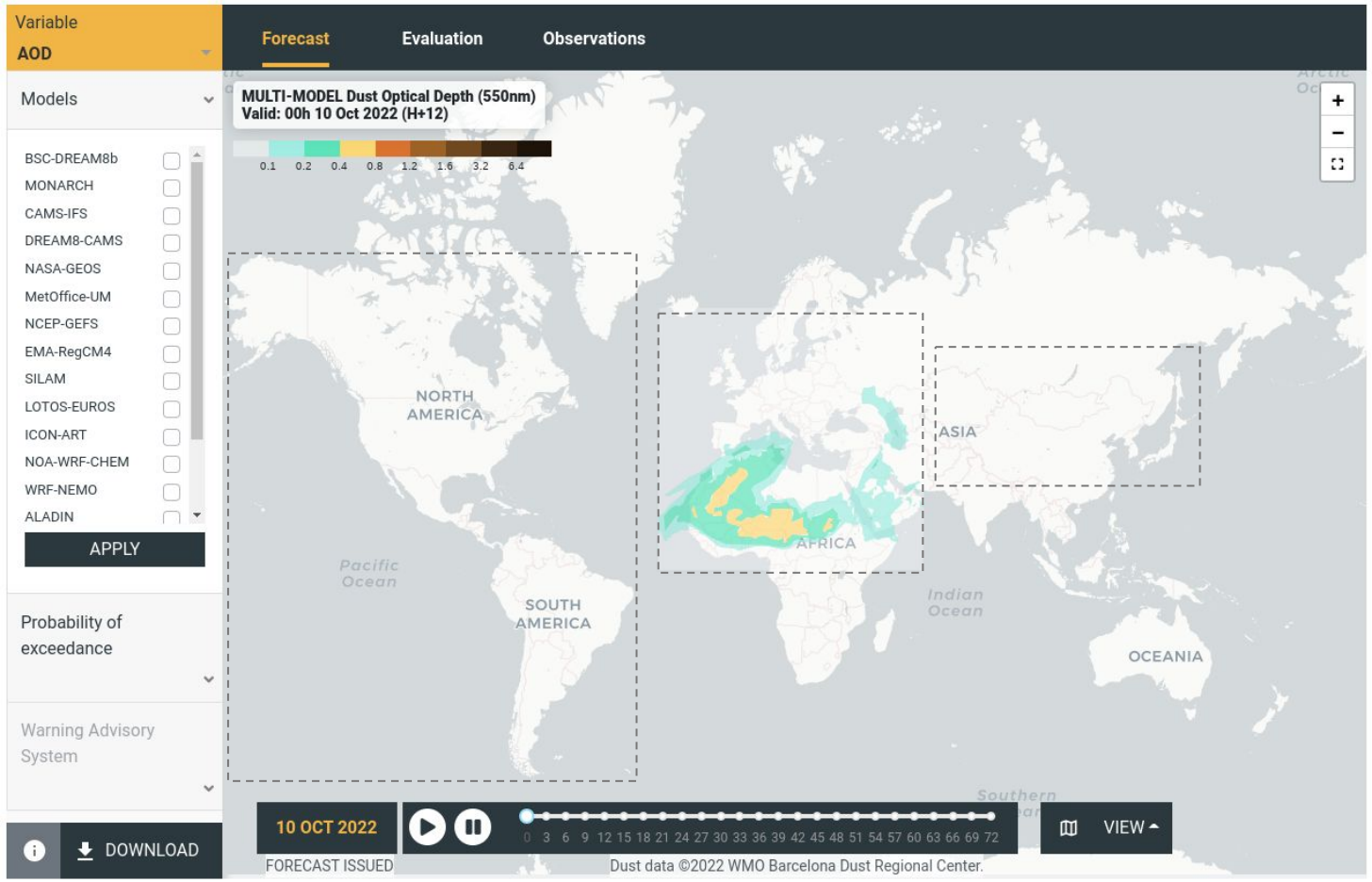

**Daily dust forecasts from 15 regional and global models** that are evaluated with AERONET and MODIS

**Tailored products:** Probability of exceedance and Warning Advisory System

**Easy access to numerical data** through a THREDDS system

Note that **five ICAP global models** are considered in the intercomparison

# WMO SDS-WAS & ICAP




Ongoing discussions to provide a **global dust forecast** product based on **ICAP**

It should be used for the three Regional Centers of the WMO SDS-WAS (i.e. NAMEE, Asia and Pan-American)

# Other products:

## Contribution to the CAMS regional ensemble

## Regional dust forecasts

## DustClim 10-yr dust reanalysis

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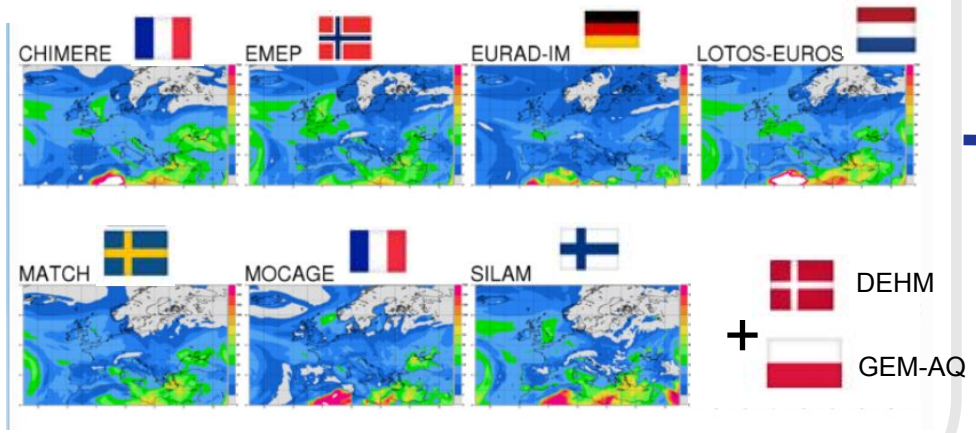
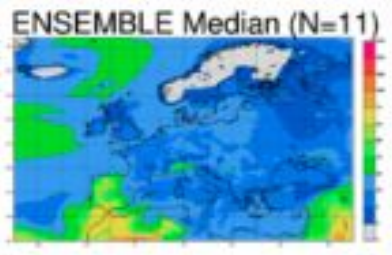
# Copernicus Programme: Regional Air Quality Products

## Operational Europe-wide Air Quality Service based on:

### 9 operational AQ models




### 1 ENSEMBLE model




**How?** Median of the individual results for each grid-cell
**Why?** Reliable, robust, performing

New operational models June 2022

MINNI (ENEA)
MONARCH (BSC)

Users

| NRT Forecasts and Analyses Daily | Interim & Validated Reanalyses Annually |
|---|---|
| METEO FRANCE | INERIS |

O3, NO2, SO2, CO, PM10, PM2.5, SIA, Dust, Pollen (6).

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https://atmosphere.copernicus.eu

Copernicus Europe's eyes on Earth
European Commission

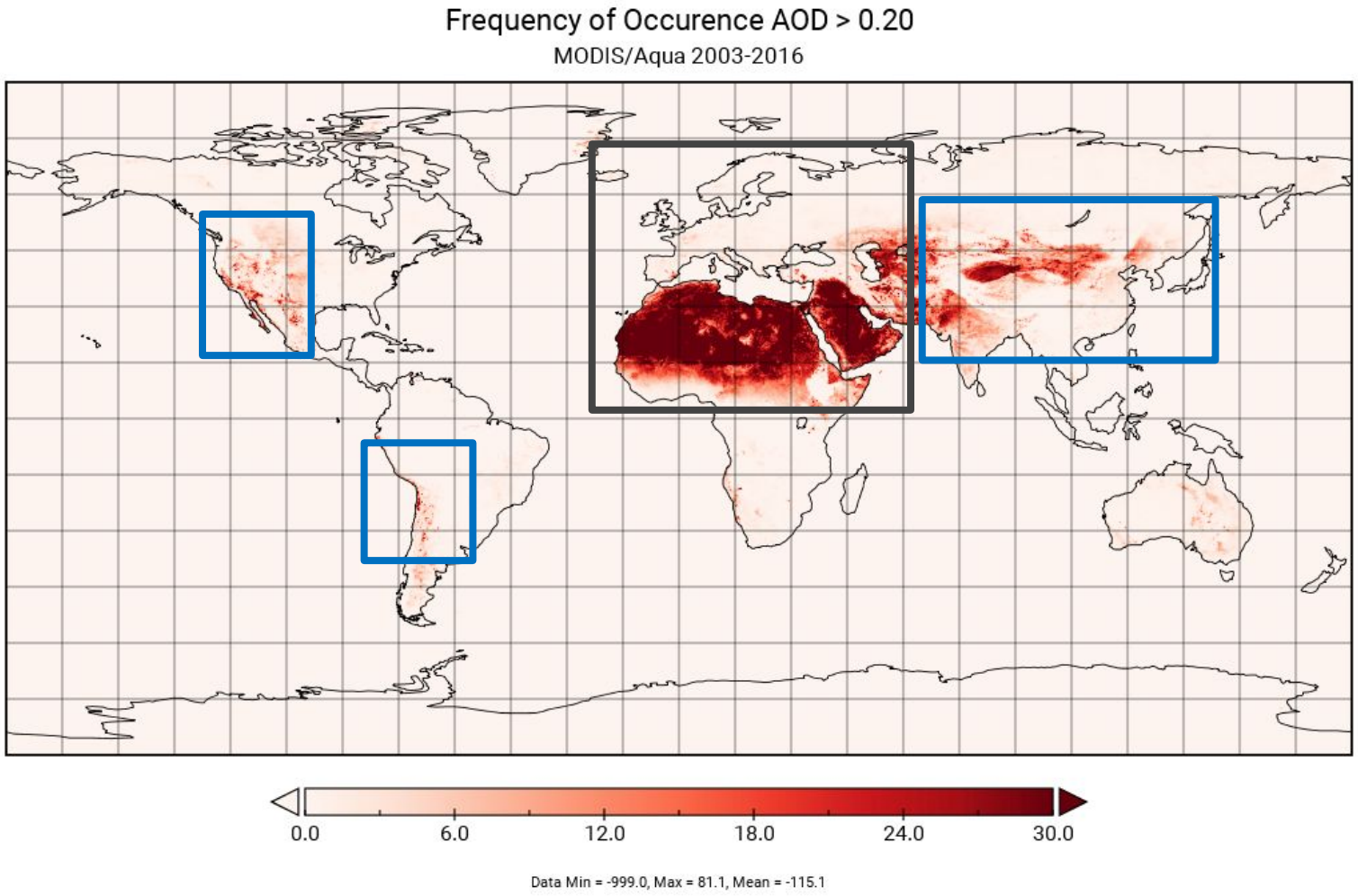
# MONARCH-REG Dust Operational forecast

Running 4 domains:

- NAMEE is operational since 2010
- China, Colorado and Chile started operations in October 2021 within the EU AQ-Watch project

Upgrades (expected for February 2023) for NAMEE includes:

- The use of the latest MONARCH code version (Klose et al., 2021)
- Revision of the calibration coefficients for wet and dry deposition.
- AOD considering triaxial spheroids (~ 2 times larger than spheres)

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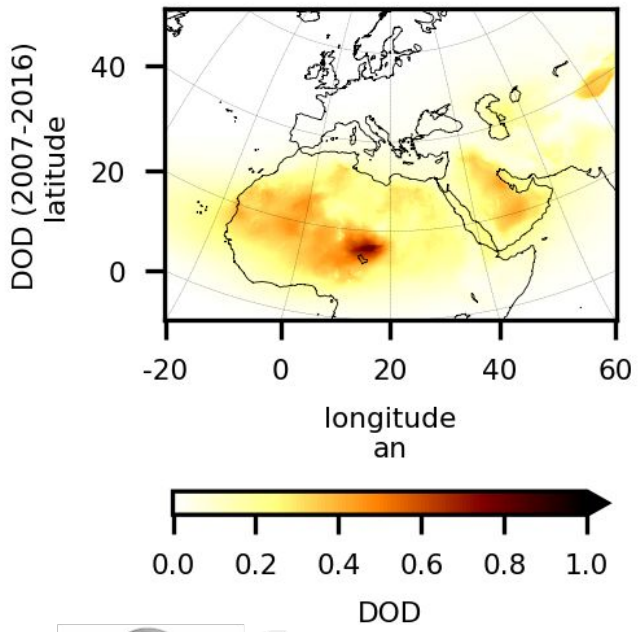
# MONARCH high-resolution reanalysis data set of desert dust aerosol over Northern Africa, the Middle East and Europe

A complete and consistent, four dimensional, regional reconstruction of desert dust in a recent decade (2007-2016)

- ✔ Unprecedented **high resolution**: 0.1º x 0.1º
- ✔ Specific **dust observational constraint**
- ✔ **Uncertainty estimates** in the reanalysis output
- ✔ Link to specific **air quality** and **climate services**
- ✔ **FAIR** data guidelines




**Open access. To request access to the repository, please contact reanalysis.access@bsc.es**



**Dataset PID:** http://hdl.handle.net/21.12146/c6d4a608-5de3-47f6-a004-67cb1d498d98

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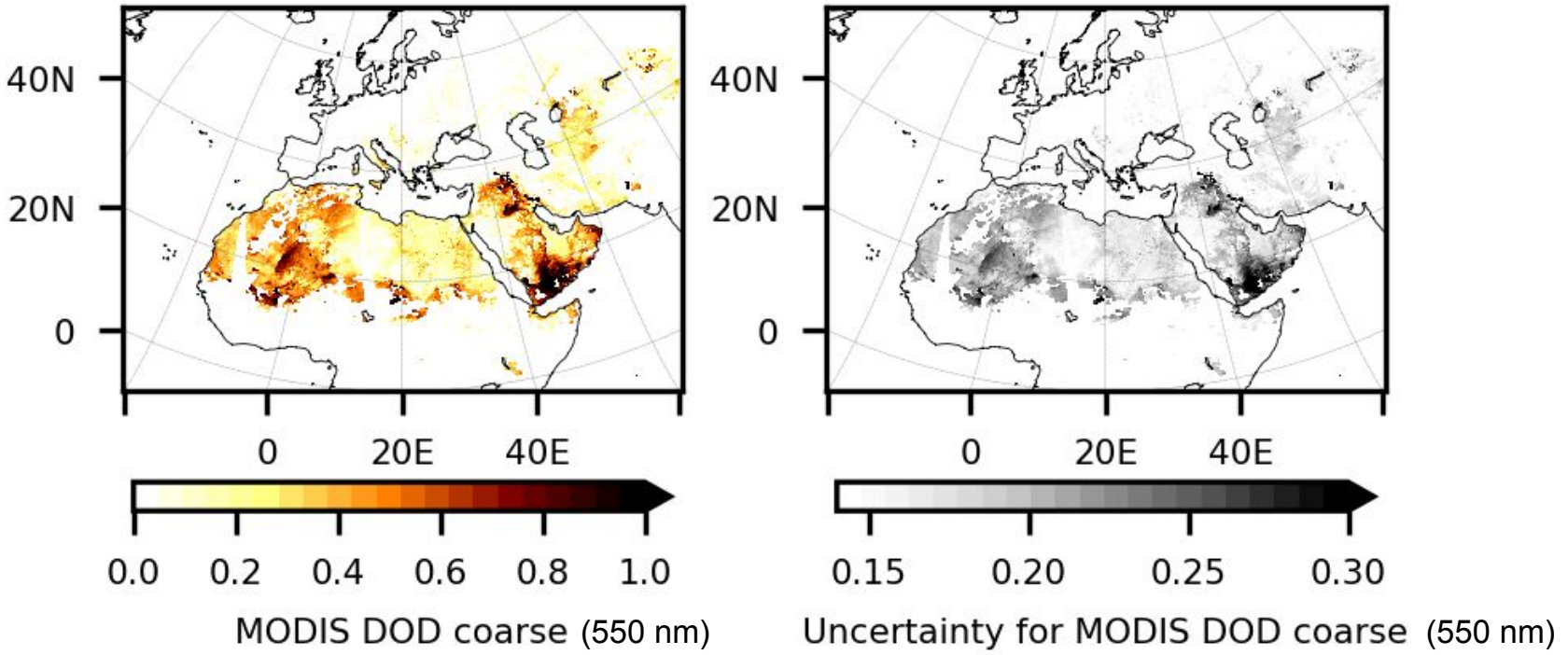
DustClim
ERA4CS European Research Area for Climate Services
BSC
AEMet Agencia Estatal de Meteorología
cnrs

*Di Tomaso et al., 2022, ESSD*

# Assimilated observations: a daily sample




- Coarse-mode dust optical depth retrieved from MODIS Deep Blue L2 aerosol products over cloud- and snow-free land surfaces (Ginoux et al. 2010, 2012; Pu and Ginoux 2016):
  - interpolated to a regular grid of 0.1 by 0.1 degrees
  - AE, ω filter, coarse AOD retrieval by an empirical continuous function (Anderson et al., 2005)
  - highest quality flag

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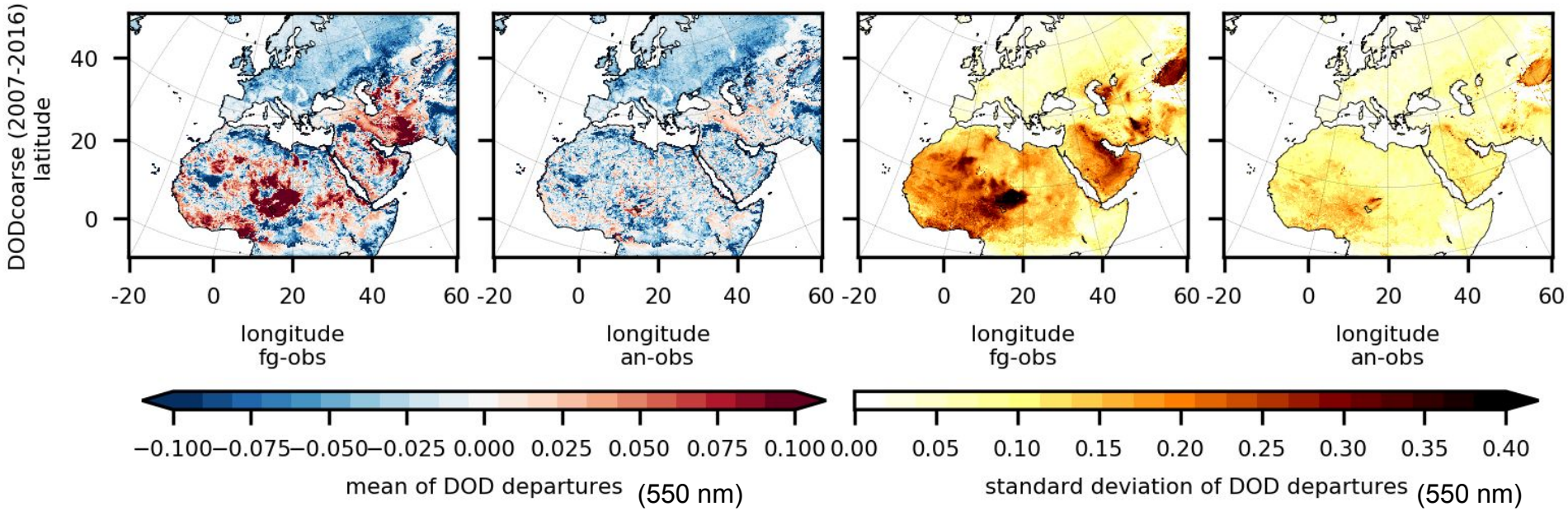
~120,000 observations assimilated daily (after quality control)

# Departures from assimilated observations




- The **reduction of the standard deviation** of the analysis departures compared to the first-guess proves the consistency of our assimilation procedure
- The **positive mean departures decrease** considerably in the analysis compared to the first-guess
  - Some of the **negative mean departures** remain unchanged: lower DOD not analyzed efficiently or contamination of other aerosols than dust in the observations

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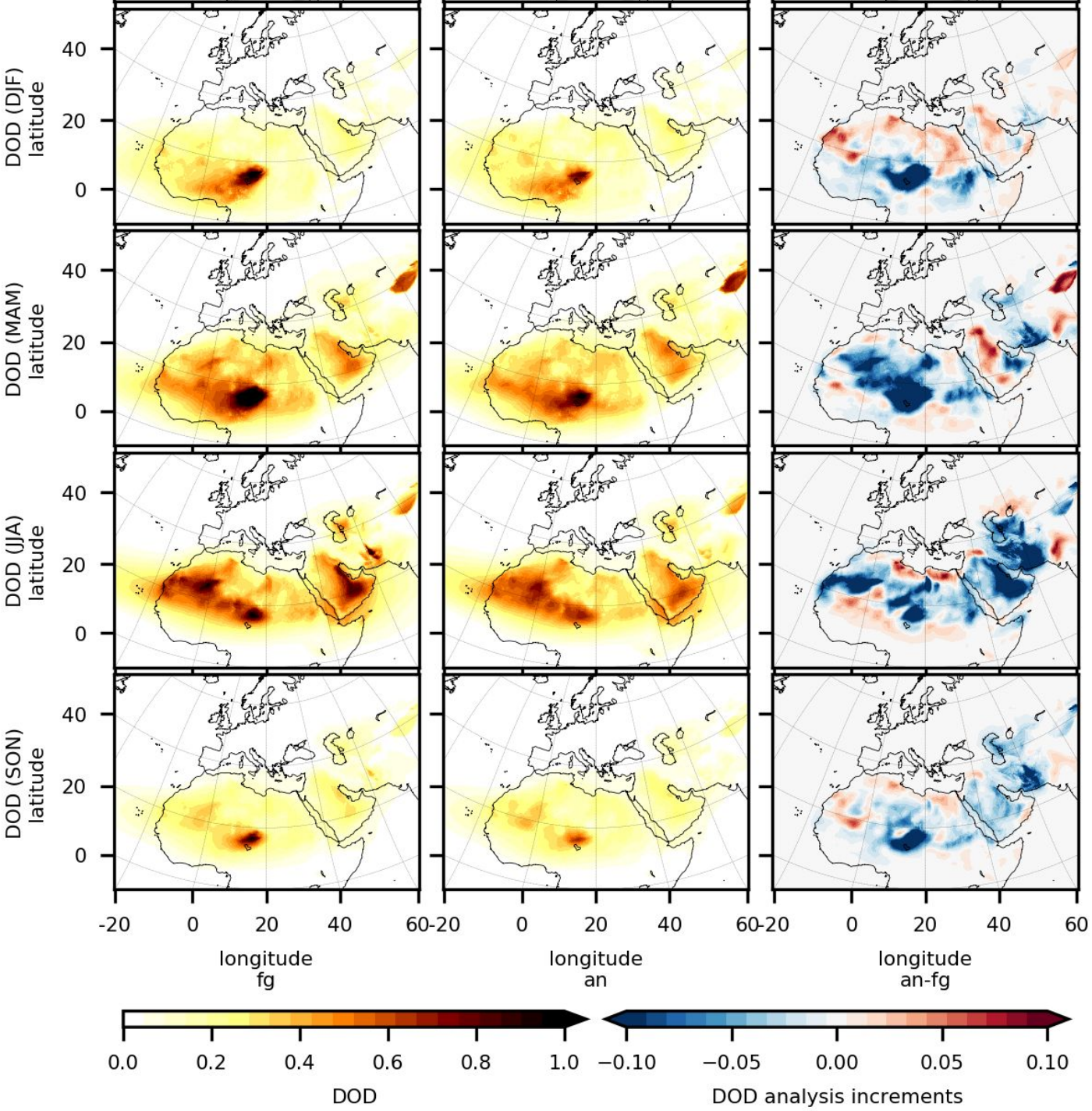
# Increments

- **Systematic negative corrections** likely linked to overestimation of the major sources' strength in Africa and the Middle East (the Bodélé depression in Chad, in the Saudi Arabia lowlands and in the Balochistan region of south-western Asia) or too weak deposition
- **Positive mean increments** over the Thar desert, in the north part of Syria, inland from the Mediterranean sea in the north of Africa, and between Mauritania and Mali

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DustClim

ERA4CS European Research Area for Climate Services

## **AVIATION.** Aircraft and airport operations, maintenance and planning

- **Visibility conditions** and **exceedance counts and probabilities** for VFR, IFR, LVP thresholds
- **Accumulated flight route exposure** to sand and dust at critical flight levels for NAMEE flight routes
- **Airport resilience classification** (to sand and dust storms)


## **SOLAR ENERGY.** Strategic investment and operations optimization

- **Soiling index** (% transmissivity reduction due to dust deposition)
- **Sunshine hours** (maximum potential sunshine, corrected for dust presence)
- **Optimal cleaning frequency** (frequency of cleaning to operate with profit)


## **AIR QUALITY.** The mineral dust component and its health and regulatory implications

- **Climatology and validation of dust contribution to PM10** at the ground in source and downwind areas
- **Desert-dust driven exceedances of PM10 thresholds** fixed by EU legislation and WHO AQ Guidelines
- **Exposure of population** to desert-dust PM10
- **Use of climatology** to feed an in-progress **Early Warning System** for air quality

***DustClim methodology** is used in the recent UN ESCAP-ADPIM Sand and Dust Storms Risk Assessment report*

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BSC AEMet Agencia Estatal de Meteorología cnrs

# Research activities


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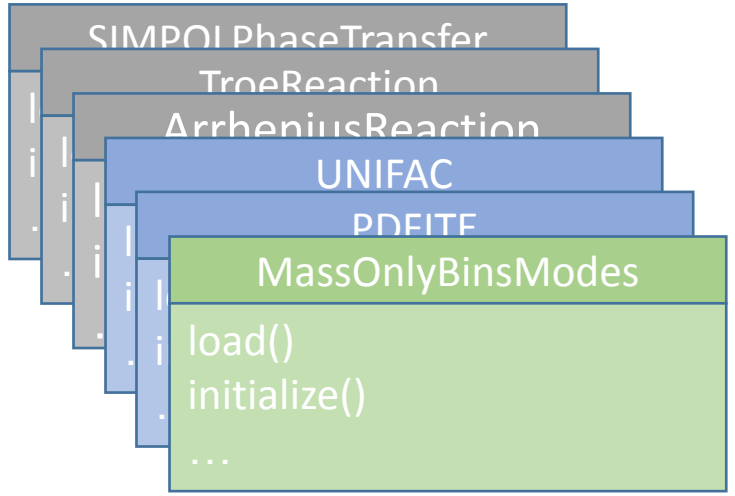
# CAMP: Chemistry Across Multiple Phases

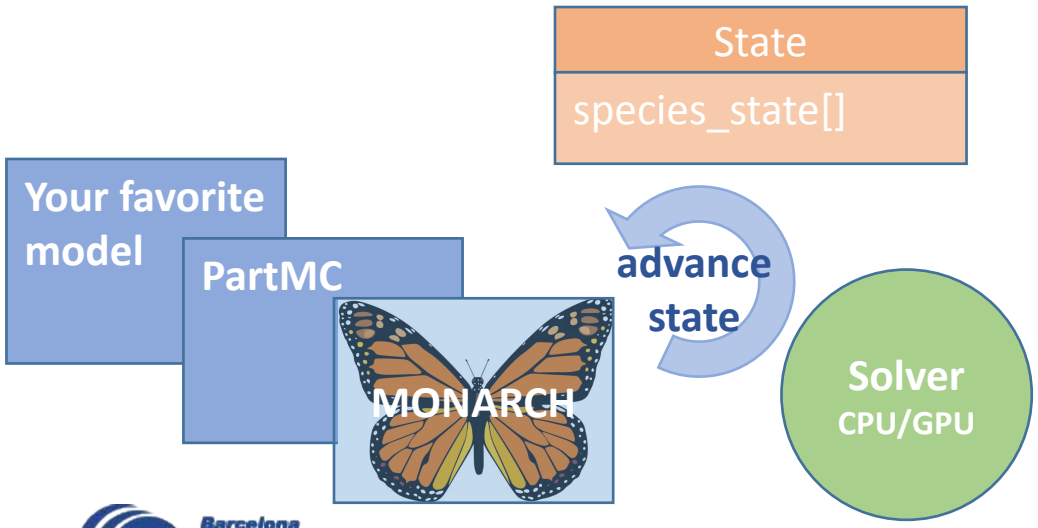
- Scalable kinetics treatment for chemistry in multi-phase models
- Change the chemical mechanism ***without recompiling***
  - Vary mechanism complexity based on conditions/location
  - Compare mechanisms in real time
- Use ***same mechanisms*** across models (MONARCH, PartMC, etc.) changing only **Aerosol Representation** JSON

USER

```
{
  "reactants" : {
    "O3" : {} ,
    "NO" : {}
  },
  "products" : {
    "NO2" : {}
  },
  "type" : "ARRHENIUS",
  "A" : 3.0E-12,
  "B" : 0.0E+00,
  "C" : -1500.0
}
```

**Load input files into model objects**




Condensed Data Structure

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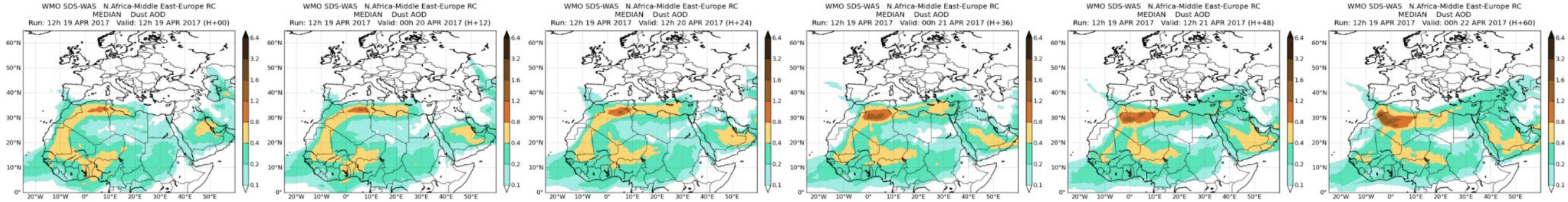
Dawson et al. (2021 GMD)

**The CAMP library is available at:** https://github.com/open-atmos/camp

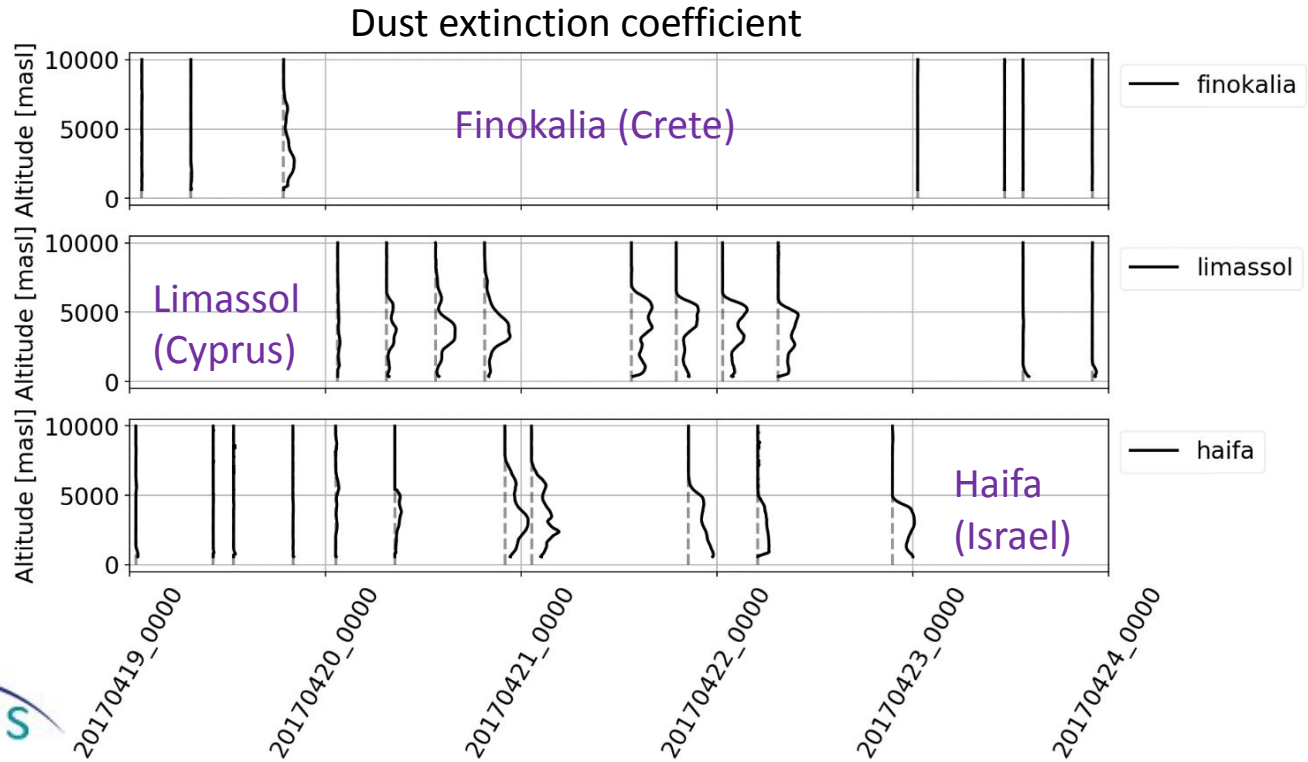
# Assimilation of LIVAS extinction coefficient profiles

Three-dimensional analyses of atmospheric dust aerosol concentrations constrained by satellite vertical retrievals of dust properties, and associated uncertainty estimation.




Event observed by 3 **lidar** sensors located **in Finokalia (Crete), Limassol (Cyprus) and Haifa (Israel)** part of the PollyNet (http://polly.tropos.de/) system. Data (with uncertainty estimation) processed by TROPOS.

*Escribano et al., 2022, ACP*

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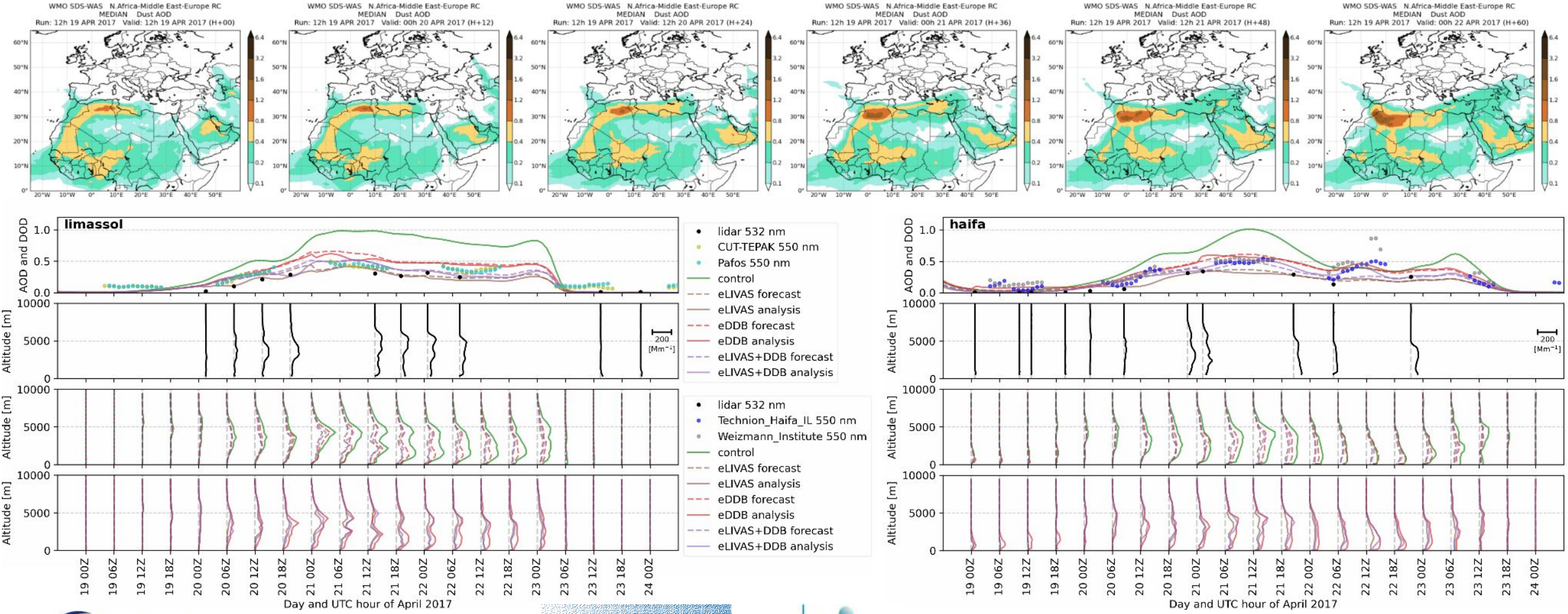
TROPOS
Leibniz Institute for Tropospheric Research

ACTRiS

# Assimilation of LIVAS extinction coefficient profiles

Three-dimensional analyses of atmospheric dust aerosol concentrations constrained by satellite vertical retrievals of dust properties, and associated uncertainty estimation.

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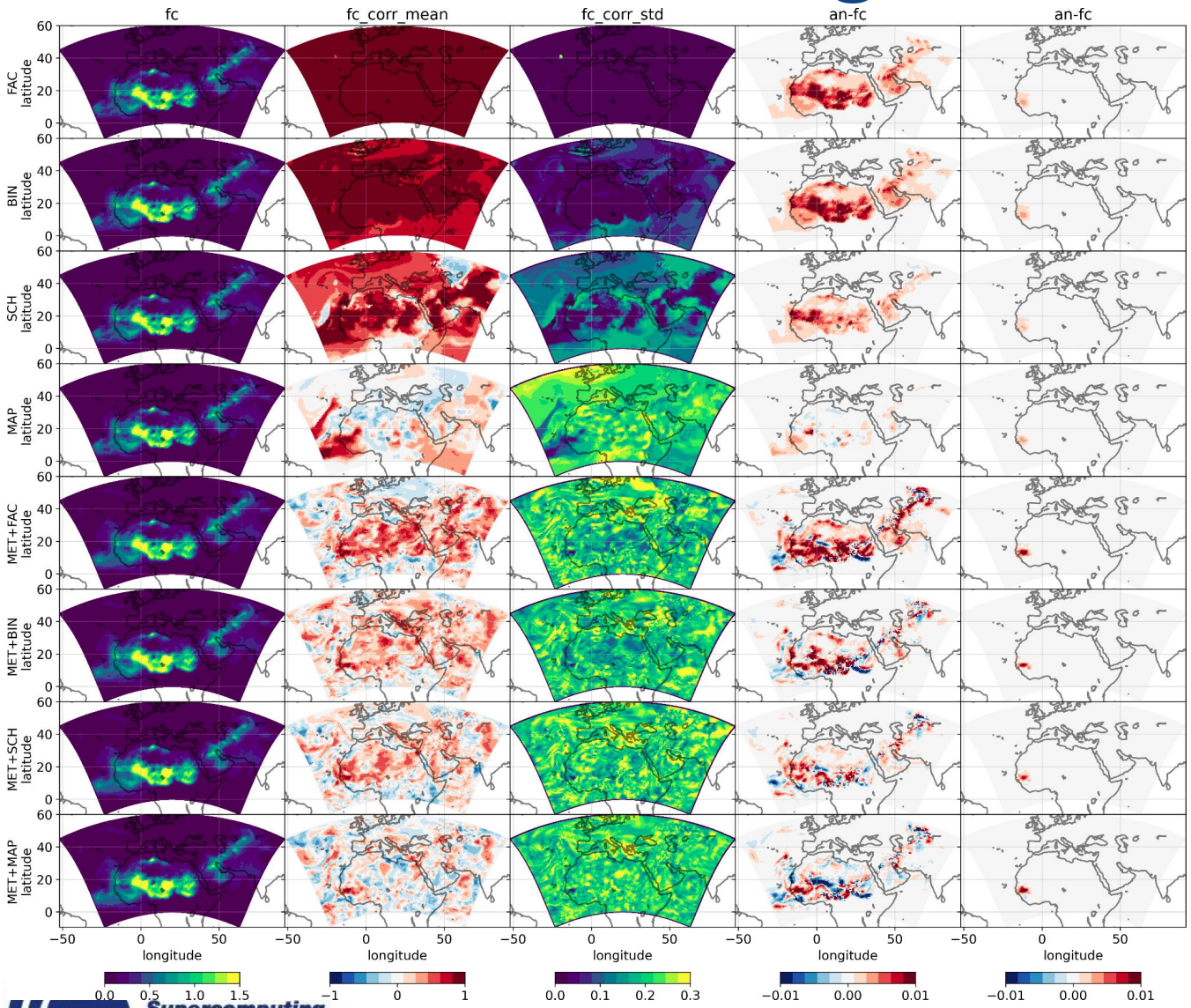
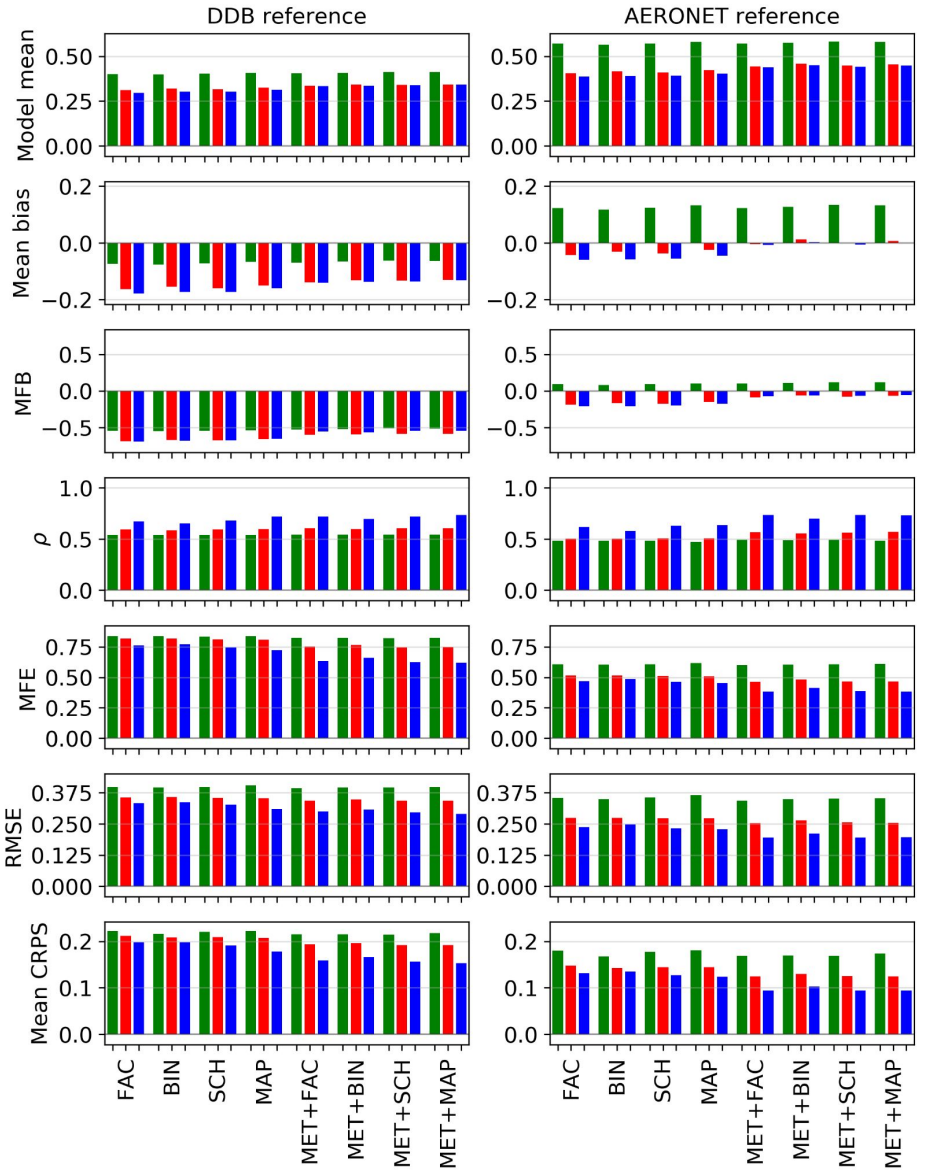
TROPOS
Leibniz Institute for Tropospheric Research

ACTRiS

*Escribano et al., 2022, ACP*

# Ensemble generation for dust DA

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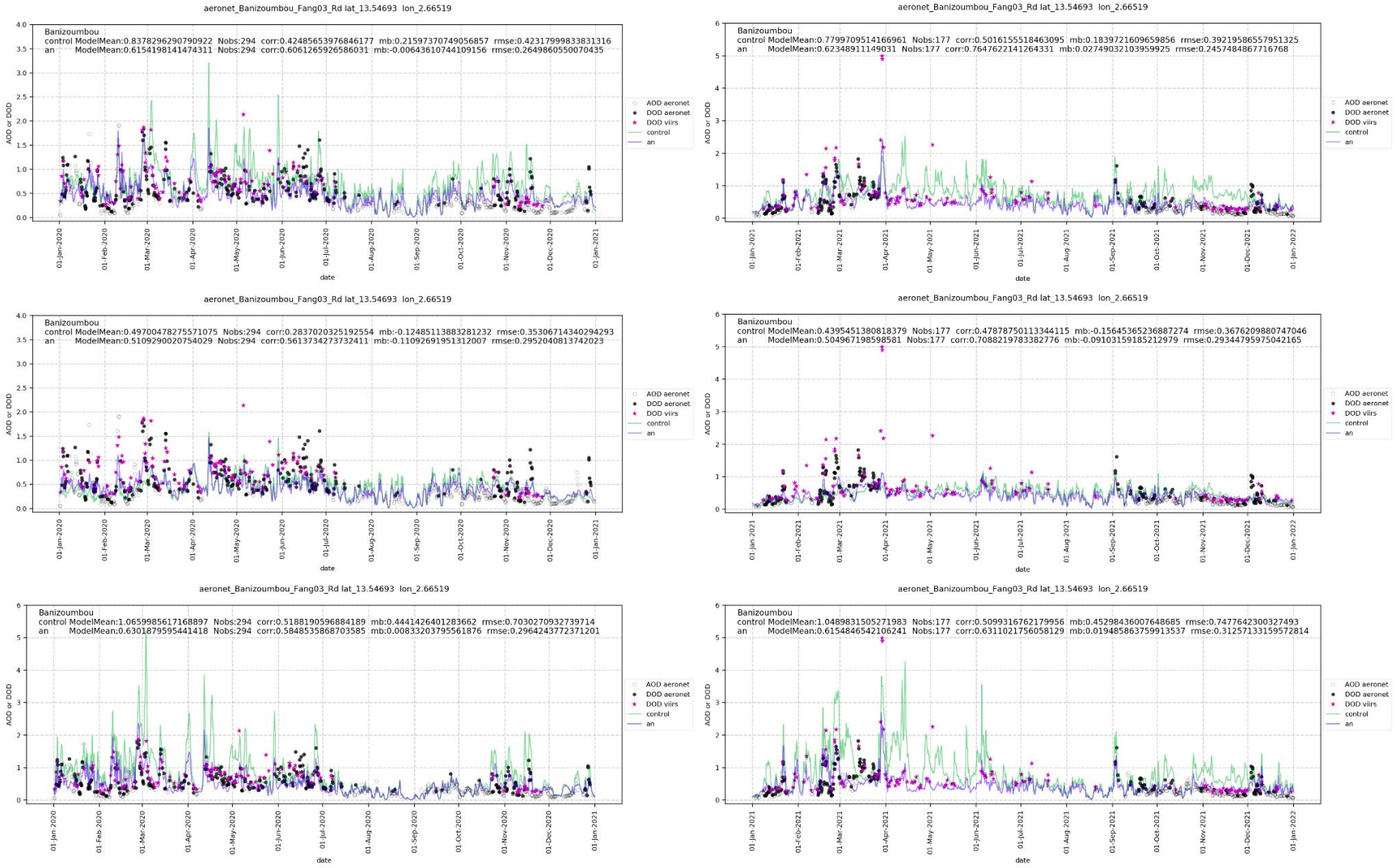
# Dust emission top-down inversion/estimation

- Only dust emission in control vector of DA, based on LETKF, and assimilating SNPP-VIIRS DB AOD.
- 5 years: 2017-2021
- 3 dust emission schemes (runs): Ginoux-GOCART (top), Kok2014 (middle) and Shao2012 (bottom) emission schemes (as in Klose et al 2021 GMD)

Banizoumbou 2020 and 2021 ( Aeronet ALM v3L1.5 , interp 550nm, ang<0.3, Rd).

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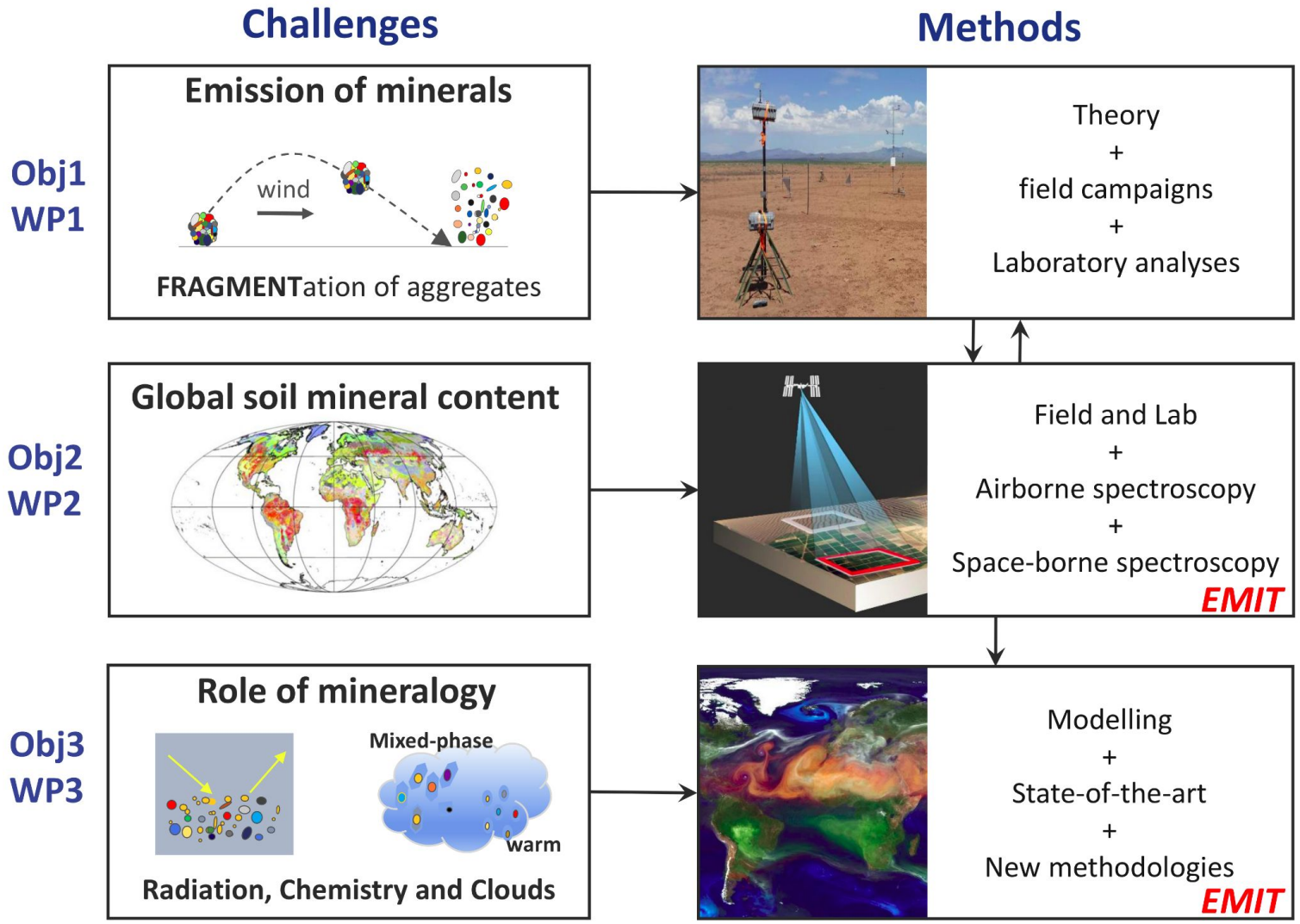
# FRontiers in dust minerAloGical coMposition and its Effects upoN climaTe (FRAGMENT ERC)

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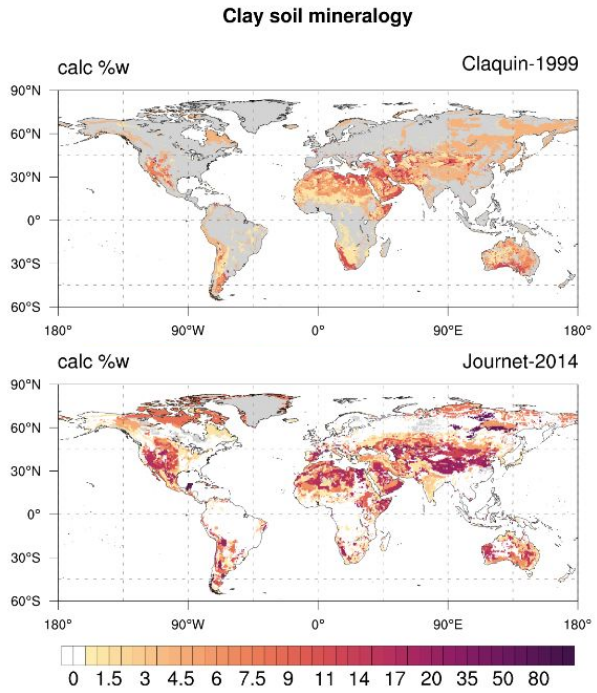
# Research on dust mineralogy and its impacts on the Earth System

**MONARCH** has been developed to explicitly represent dust mineralogy, with the aim of improving our knowledge on its impacts in the Earth System (e.g. interaction with radiation, atmospheric chemistry).

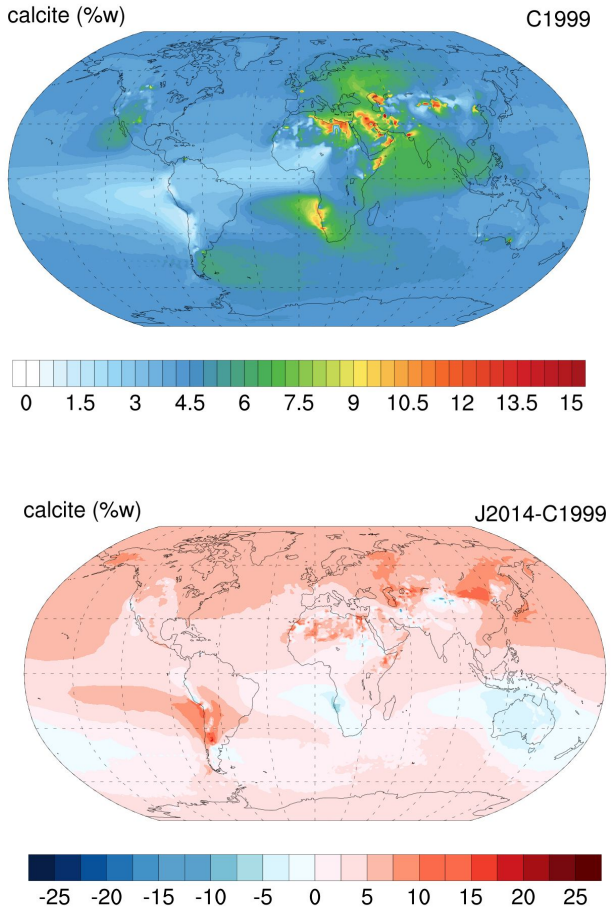
**2 state of the art Mineralogy Atlases:**

*Claquin et al. (1999), Nickovic et al. (2012)*
8 minerals:
Illite, smectite, kaolinite, quartz, feldspars, calcite, gypsum and hematite (iron oxides).

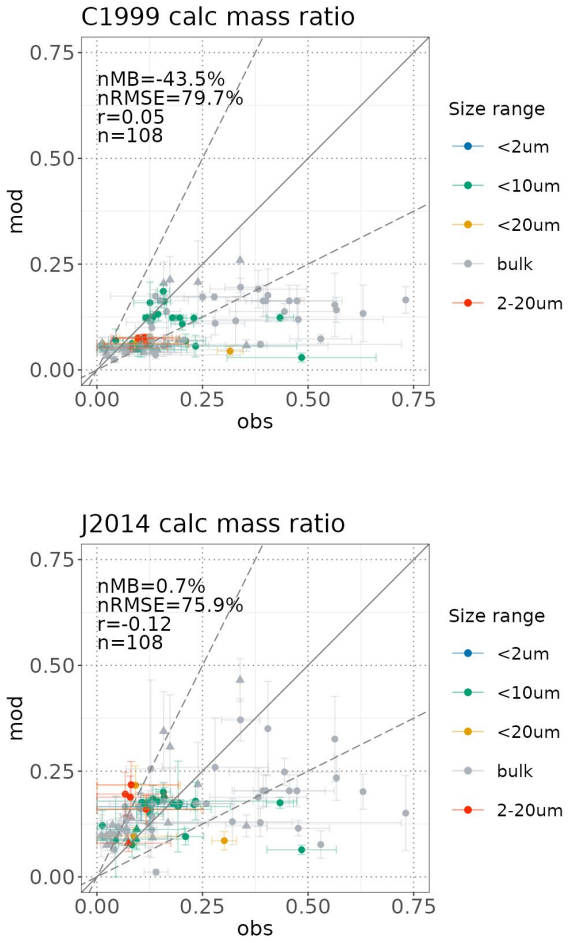
*Journet et al. (2014)*
12 minerals:
Illite, smectite, kaolinite, vermiculite, chlorite, mica, quartz, feldspars, calcite, gypsum, hematite and goethite.




**Mineral fraction at surface conc.**
(MONARCH 2006-2010, %w)




Evaluation against observations
(following Perlwitz et al. 2015)

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# thanks!

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